ADVANCED FIELD DATA ACQUISITION

TECHNIQUES FOR

CONTAMINATED SITE CHARACTERIZATION

Presented to:

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INTRODUCTION

The continual need to apply the latest technologies to enable better characterization of subsurface anomalies in conjunction with accurate mapping and locator techniques is typified by the introduction of the Ultra Sonic Range Acquisition Data System (USRADS).

The system is a complete computer based device that automates the measurement, data collection , and mapping of environmental survey data. USRADS automatically determines a surveyor's XY- position in the field using "time-of-flight" information and links this with the surveyor's instrument readings, via radio transmission, to a portable computer. USRADS analyses and presents "real time" data at the site. USRADS is interfaced with the latest field instruments for assessing and evaluating surface and subsurface anomalies, e.g. radiation, ordnance, trenches, pits, and hazardous waste surveys.

The original USRADS was developed by Oak Ridge National Laboratory (ORNL) as part of the Department of Energy's Uranium Mill Tailings Remedial Action Project. The system was developed to increase the speed and accuracy and simultaneously lower the expense of creating survey grids for geophysical surveys.

1.0 THE USRADS/UXO SYSTEM

The original USRADS system developed by ORNL uses a computer interface with a Geonics EM31 terrain conductivity meter. The USRADS operator carries a transducer in a backpack, which sends ultrasonic pulses to microphones deployed in the survey area. A microprocessor-controlled radio transmitter, also carried in the backpack, transmits terrain conductivity data to a mobile base station, where the operator's grid position, electromagnetic quadrature, and inphase readings are automatically recorded each second by a portable computer. The system was found to be accurate to 10cm up to a distance of 120 meters. After initial testing and development, a licensing agreement was signed with Chemrad Tennessee Corporation, located in Oak Ridge, Tennessee, to further develop the system for use in real-time environmental surveys.

Through agreements, EOD Technology teamed with Chemrad to through agreements to increase the instrument interfaces and application to sites contaminated with unexploded ordnance (UXO) and explosive wastes. The system has been successfully applied for characterization of such sites for the U.S. Army Corps of Engineers, Huntsville Division, and USTHAMA.

2.0 DESCRIPTION OF HARDWARE/SOFTWARE

Hardware

USRADS consists of a surveyor datapack, fifteen stationary receivers, a master receiver, custom computer interface and timing circuitry, and a portable computer. The datapack contains the interface circuitry to receive the signal from the field instrument, an ultrasonic transmitter, radio equipment, and on-board micro computer to establish bi-directional communications with the computer, and a handheld terminal for communications between the surveyor and the computer. The stationary receivers are used to determine the ultrasonic time-of-flight information from the surveyor datapack which allows the computer to calculate and plot the surveyors location each second. The master receiver provides for the radio telemetry links between the datapack and stationary receivers to the computer. The computer performs the positioning calculations, stores the location/detector data, displays the surveyor location with corresponding data in real-time, and performs in-field analysis of the USRADS survey data.

Software

The USRADS software includes routines for Setup, Survey and Analysis. Setup routines are included to check the equipment operation, to locate the stationary receivers, and to calibrate the system for ultrasonic accuracy. Setup also automatically draws the site map on the computer screen, scaling and orienting the map as required. Survey routines display the site map on the computer screen, collect, store, and plot the surveyor location and corresponding detector data once each second, in real-time. If the data for a particular location is greater than the operator specified threshold, then that location is highlighted on the computer display. In this manner, those areas exceeding the threshold criteria are determined as the survey progresses.

USRADS analyze routines are include to perform analysis if the USRADS data while in the filed immediately upon conclusion of the survey. Theses routines include numerous different types of graphical display formulas including Track Map Replay, Block Statistics, Contour and 3-D plots of the data. The Replay program generates the same display that the surveyor viewed when the survey of the property was completed, while varying the data threshold of interest. The Block Statistics routine enables the operator to select a grid block size and have the data statistically analyzed for each block (number measurements, measurement range, average and standard deviation). Utility routines are also included to convert the data to formats compatible with the most popular software packages used for contouring routines, spreadsheets, databases, and Autocadd.

3.0 SYSTEM OPERATION

To operate USRADS, the user generally places four or more stationary receivers on the site around the area to be surveyed. Next, the location of the stationary receivers are precisely and automatically determined using the USRADS ultrasonics. Through the Setup computer routines, the computer automatically draws the survey site on screen with x,y axis oriented as specified by the user and at a scale to encompass the most distant stationary receivers. Then the surveyor, wearing the datapack (or vehicle mounted), covers the site at a constant rate in the desired pattern of survey coverage. The rest is automatic. The ultrasonic crystal pulses once each second as the data from the portable survey instrument is automatically transmitted to the computer via radio telemetry link. The corresponding ultrasonic time-of-flight information is used by the computer to determine the surveyors location. The computer plots the surveyor position on the CRT, with an indication of any locations that have detector readings which exceed a user specified threshold. During the survey, the surveyor controls the conduct of the survey through the use of the handheld terminal that is connected to the surveyor datapack. The handheld terminal reports the surveyor location or the current detector data, as desired. The surveyor can also suspend the survey, enter comments to the file, select the type of display, and terminate the survey from the handheld terminal.

3.1 USRADS Capabilities/Applications

USRADS automatically determines and maps environmental suspect locations and simultaneously logs related detector data, with comments, as desired, tied to the computer map files for subsequent review and presentation, and analysis. USRADS determines the surveyor position to $\pm$ six inches, once per second, displays the surveyors x, y, /coordinates on the handheld terminal, and allows the surveyor to enter comments to computer file from the handheld terminal. Optional configurations can log either 1, 3, or 6 channels of detector data once each second through analog, serial, or parallel interfaces to the datapack. USRADS provides automatic site map generation, real-time display of surveyor location, tracking of any corresponding detector data, and immediate availability of USRADS data for analysis in the field. USRADS can convert data to ASCII format and others, as required for use commercially available GIS/LIS analysis, data base, and presentation software.

3.2 USRADS/Radiation Surveys

Detects, measures, and maps radioactive contamination and radiation dose rates. Interfaces with most popular radiation detection devices (indoors/outdoors).

3.3 USRADS/EM31 Terrain Conductivity Surveys

Non intrusively measures and maps underground features and objects such as subterranean contours of land fill sites, locations of buried metallic objects, and location and extent of underground plumes of subsurface liquid flows up to eighteen (18) feet in depth.

3.4 USRADS/XMET 880 X-ray Florescence Surveys

Measures and maps elemental species of hazardous material pollution in surface soils such as lead, zinc, mercury, arsenic, etc. (Z number > 13).

3.5 USRADS/UXO MAGNETOMETER -

Schonstedt GA-52B and Schonstedt GA-72C/V non intrusively measure magnetic anomalies and variation accurately to a depth of five (5) feet, highly suitable for detection of unexploded ordnance and ordnance debris.

Other system options with USRADS can be readily used with up to an array of six (6) different sensor systems or a mix of sensor types depending upon the objective of the survey. Other measurement instruments such as gradiometers, vapor detectors,noise meters, and light meters can be easily interfaced with the system.

4.0 EMPLOYMENT OF USRADS/UNEXPLODED ORDNANCE SYSTEM (UX0)

The USRADS/UXO system has been deployed in the characterization of suspected Ordnance Explosive Waste (OEW) sites to determine the extent of the problem. The system has used conductivity and magnetometer instruments individually or in parallel to enable detailed analysis to be carried out.

In remediation activities it establishes an accurate cost effective "before" and "after" surface and subsurface multi-color mapped profile and has proven to be an excellent Quality Assurance/Quality Control tool. The system has adjustable threshold limits to eliminate background distinctions such as soilbearing, ferrous oxides, or small pieces of progmentation.

4.1 Typical USRADS/UXO Protocols Utilizing Portable System (2-man team)

SURVEY: A rapid initial assessment of a cleared area utilizing 5 foot sweep lanes. 3.0 acres per 8 hour day in good open flat terrain, 3.75 acres per 10 hour day, good open flat terrain.

CONFIDENCE LEVEL: Lowest because of the rapid pace of movement. This protocol will identify burial pits, burial trenches, and large ordnance items such as bombs, and large projectiles.

REMEDIATION: A slower assessment of a cleared area utilizing 5 foot sweep lanes. Two passes over the same area (cross hatch) are made. 1.5 acres per 8 hour day in good open terrain. 2.0 acres per 10 hour day in good open flat terrain.

CONFIDENCE LEVEL: Very good because of the cross hatch. This protocol will identify burial pits, burial trenches, large ordnance items such as bombs, large projectiles and smaller ordnance items such as mortars.

QC: The slowest assessment of a cleared area utilizing 5 foot sweep lanes. Three passes over the same area are made. 1.0 acres per 8 hour day in good open flat terrain. 1.25 acres per 10 hour day in good open flat terrain.

CONFIDENCE LEVEL: Highest because of the double cross hatch. This protocol will identify burial pits, burial trenches, large ordnance items such as bombs, large projectiles and smaller ordnance items such as mortars, grenades and shrapnel.

NOTE: TERRAIN MULTIPLIERS ARE USED TO FIGURE SWEEP RATES IN TERRAIN OTHER THEN THAT IDENTIFIED ABOVE.

4.2 Interpretation of Survey Results

A full data analysis of the results requires data input from historical data and knowledge of prior usage followed by closer study of specific anomalies to quantify and identify contamination type. A hazard risk analysis can also be included as part of the interpretation of the survey results.

The graphic presentation of the data consists of Track Maps, multilevel contours and a three dimensional plot with multilevel contours plotted above the three dimensional plots so that both the magnitude of the magnetic anomaly and the relative position of the anomaly in the X, Y plane can be viewed simultaneously. In addition to the graphic presentation of the data for each survey grid, the data for each area will be consolidated into a single image. The USRADS/UXO system can be used to produce feature maps of each area during the survey.

The Feature Maps are used to document the location of landmarks or site characteristics contained within the survey areas that can aid in the interpretation of the data.

4.3 Track Maps

The color coded Track Maps document the surveyor's location and the relative magnitude (Table 1) of the signal from the survey instrument. Each dot or highlighted symbol indicates the location of a data point. The difference between the dot and a highlighted symbol is that the magnitude of the survey instrument exceeded the threshold listed at the bottom of each plot. The three-dimensional plots display the range and location of the detector signal over the entire survey area.

Signal Level	Color
0 - 299	Green
300 - 899	Blue
900 - 1199	Magenta
1200 - 1500	Yellow
1500 - Up	Red

Table 1. Track Map Color Key

4.4 Multilevel Contour and Three Dimensional Plots

Multilevel contours and the two/three-dimensional plots are provided for each of the survey grids. The multilevel contour provides a means to identify the location and relative intensity of magnetic anomalies without viewing every data point collected by the surveyor as shown by the Track Maps. The multilevel contours will be scaled to 40 feet = 1 inch or as the situation dictates and are compiled on a survey grid by survey grids basis. The two/three dimensional plots provide another means of viewing the data set for each survey grid by providing both a three-dimensional plot to illustrate the magnitude of the magnetic signal and by placing the multilevel contour above the three-dimensional plot helps identify their location in the X, Y plane.

The minimum contouring interval for the example site is selected to provide the best signal to noise ratio. For the example site the minimum contour value was selected to be 150. The contouring interval for the data set was set to be 100. The color for the different contouring levels are listed in Table 2.

Signal Level	Color
0 - 149	Black
150 - 299	Brown
300 - 449	Green
450 - 599	Blue
600 - 749	Yellow
750 - Up	Red

Table 2. Multilevel and 3D Color Key

4.5 Consolidated Plots

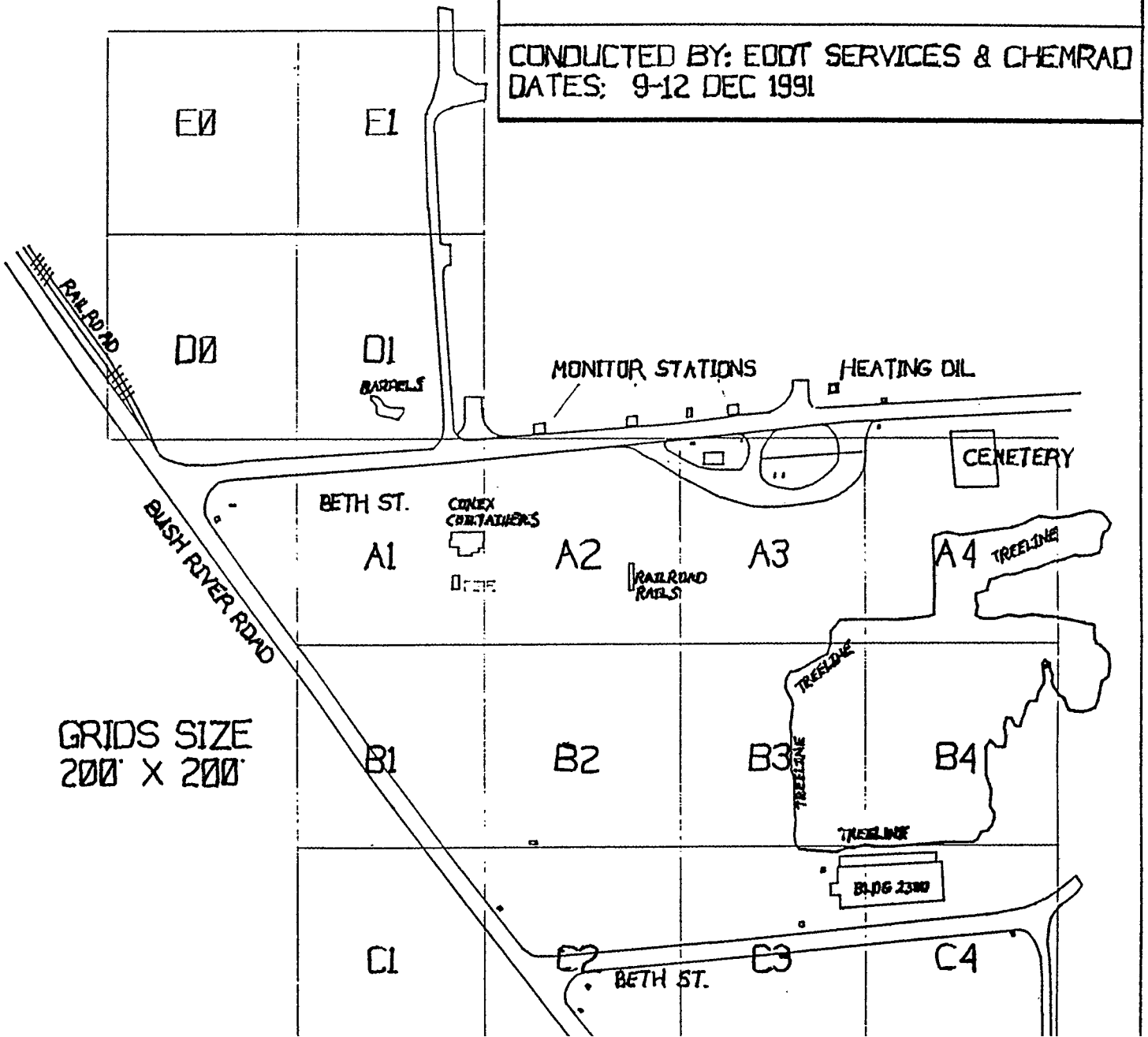
The survey data collected for the example site has been consolidated to provide an overall image for the site. The consolidated image for the site was divided into two separate images due to the shape of the site. The consolidated images are presented in both the multilevel contour format and a three-dimensional plot. The color keys for the consolidated images are the same as listed in Table 2.

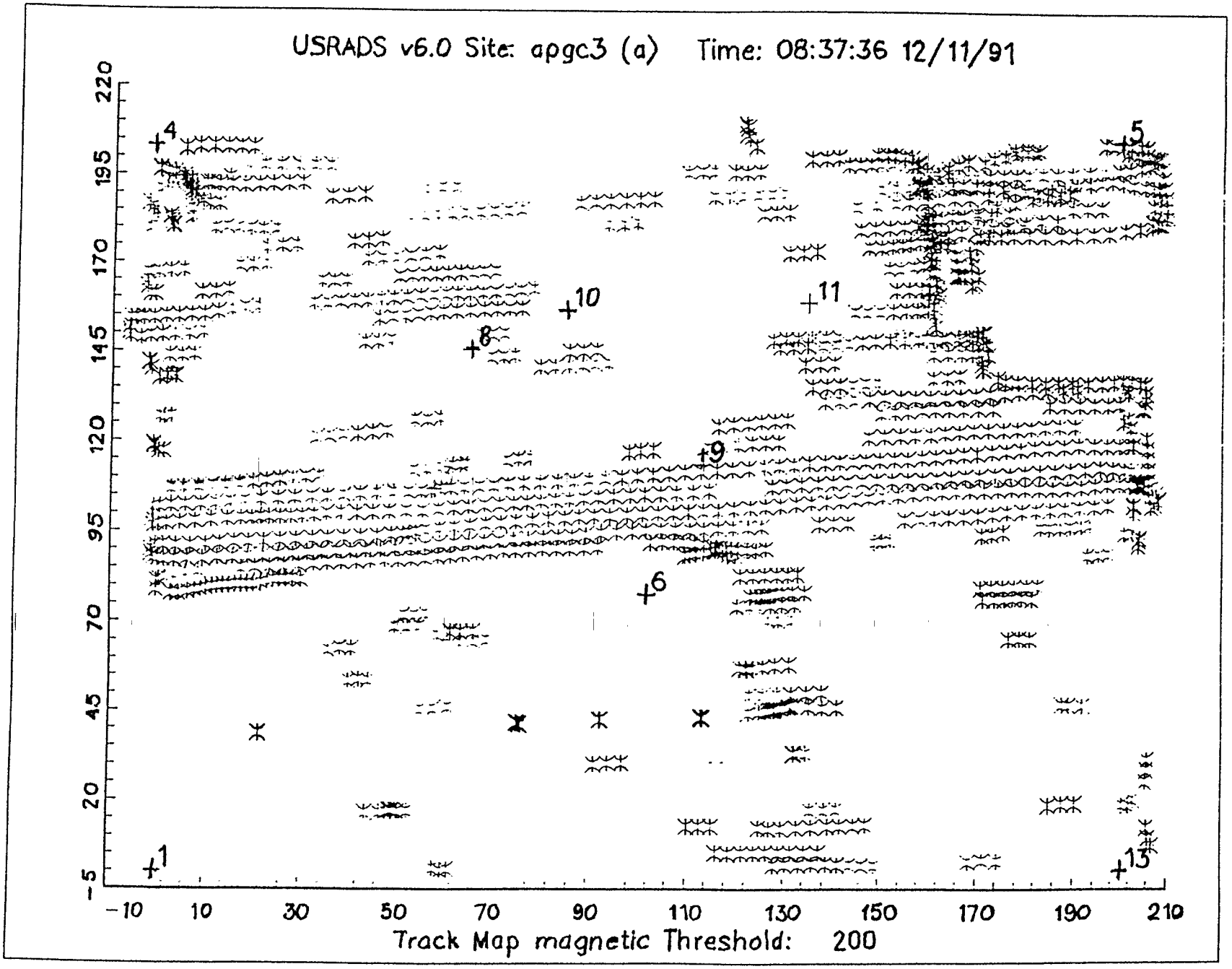
4.6 Survey Key

The file names for each survey area and the survey date are contained in the example Survey Key. Also included in the Survey Key is the statistical summary for each of the survey files. The statistical summary consists of the number of data points, the minimum and maximum signal values, and the mean and standard deviation for each data set. The data offset information are the values that were added to the survey file X and Y values so that the resulting data files for a given area could be linked together to provide a comprehensive data set for the entire area. The reference column indicates the relative sensitivity of the detector by establishing common points within an area that are tested prior to each survey to document the local area background (low) and the signal generated by placing a PK nail in the area to verify the sensitivity setting between surveys in a given survey site.

USRADS7 GXO SURVEY

CONDUCTED BY: EODT SERVICES & CHEMRAD
DATES: 9-12 DEC 1991

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170
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120
95
70
45
20
-5
-10
10
30
50
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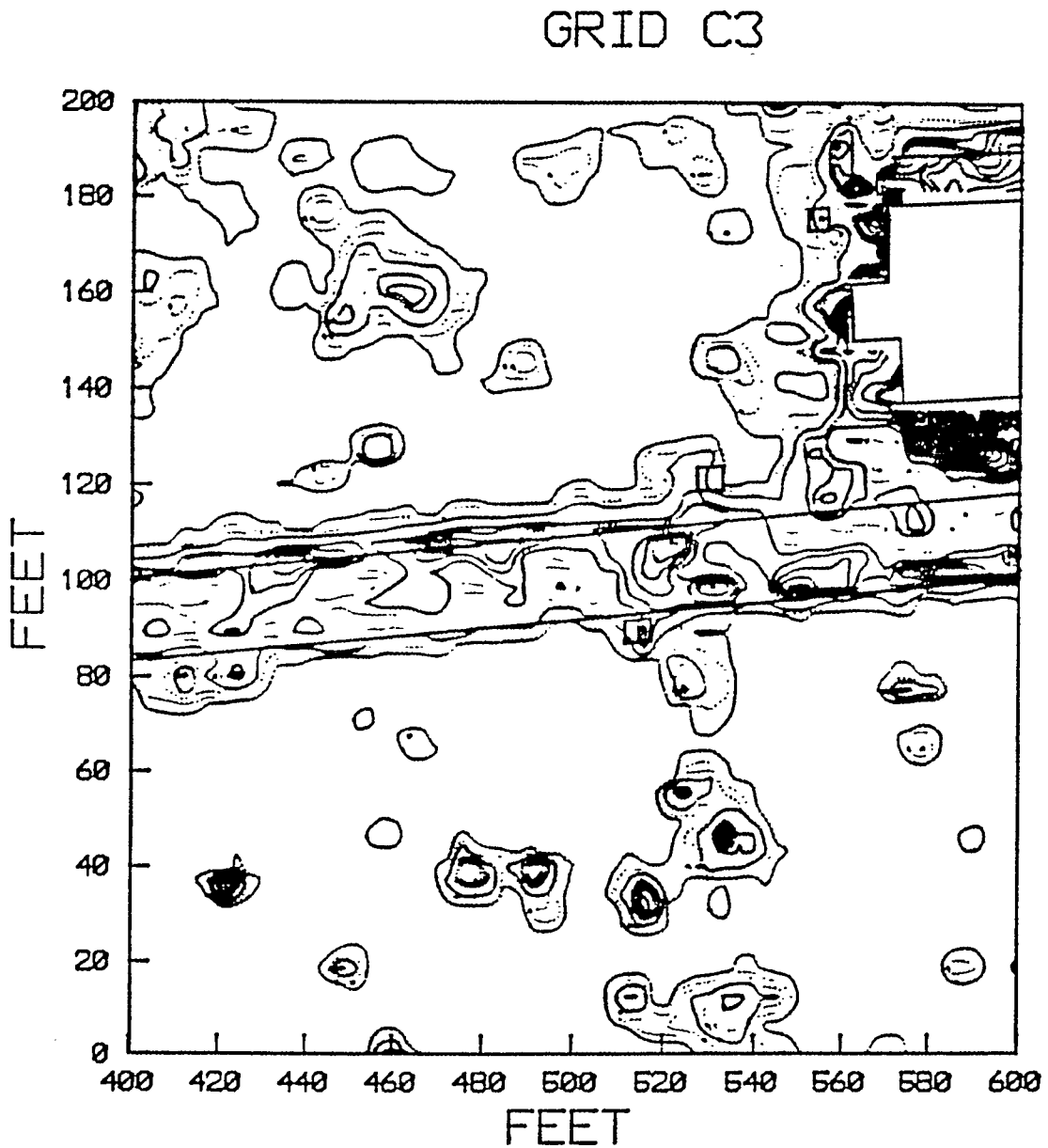
4
5
6
8
9
10
11
13


GRID C3
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160
140
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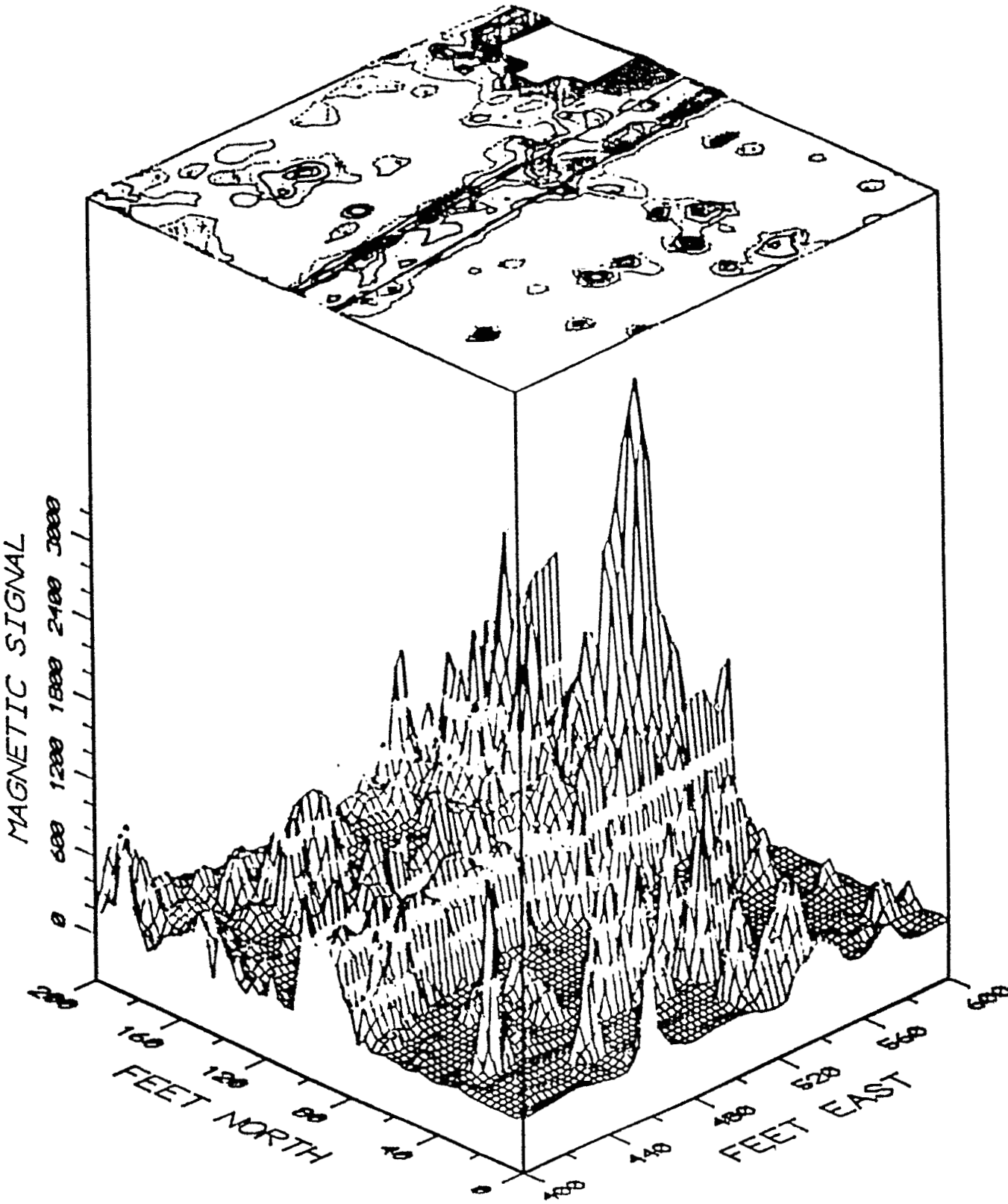
FEET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FEET NORTH
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120
80
40
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FEET EAST
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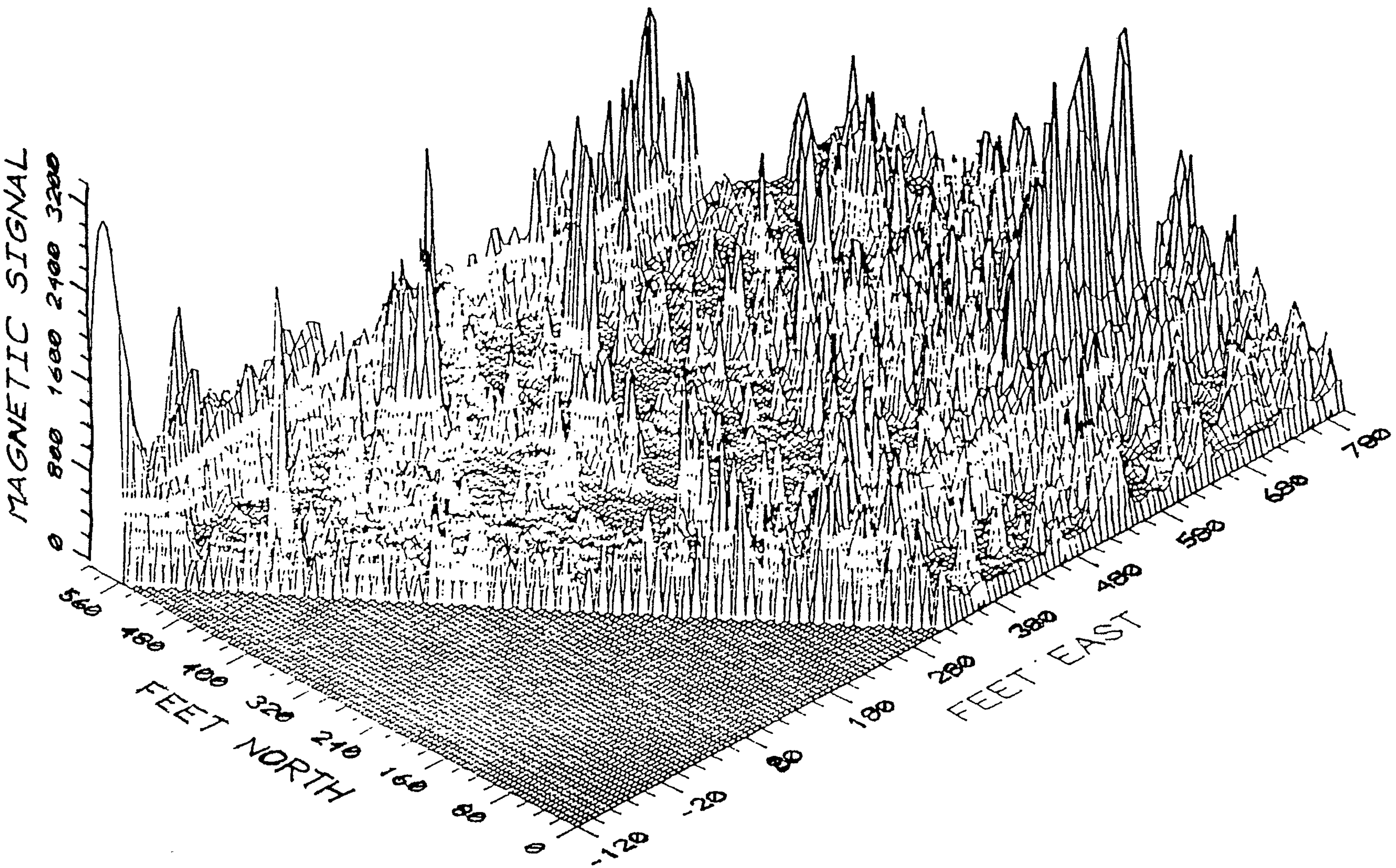
560
640

GRID C3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1600
2400
3200
FEET NORTH
560
480
400
320
240
160
80
0
FEET EAST
-120
-20
80
180
280
380
480
580
680
780

ROWS A, B, and C

5.0 CONCLUSION

USRADS offers geophysicists a number of advantages. The geophysicists in the field has the ability to monitor data as they are being collected and to refine or expand the survey coverage as required. For the interpreter the advantages include: increased spatial resolution; high data density - 3600 measurements an hour - immediately available on computer; and information on the precise location of cultural features (fences, roads, buildings, etc.) that might affect the interpretation. Theses advantages were evident in electromagnetic surveys where in two and a half hours (45 minutes survey time) including setup, take down, and some on-site analysis, 2700 quadrature and in-phase terrain conductivity measurements, were collected, and mapped.

The system operates over any terrain with good mobility, being either man portable, ATV mounted for large open areas, or robot mounted for extremely toxic environments. It offers cost advantage over current conventional methods, giving better cost control and lower cost risk.

The ability to consolidate site data through Autocadd generates a "before" and "after" action surface and subsurface profiles onto existing topographical/planimetric maps gives an accurate and permanent record and enables more detail analysis of data to be carried out, thus help to establish standards and effectiveness of remedial action. It is proven technology.

6.0 CURRENT EFFORTS AND FUTURE WORK

All field measurements involve positioning and data logging, so USRADS has many potential field applications. Currently, work is being completed for the Environmental Protection Agency to link USRADS with a portable X-ray fluorescence analyzer. USRADS offers the advantage of positioning data as well as the storing of the entire XRF spectrum for each measurement, not just the metal assays. With the whole spectrum it will be possible to reanalyze the data using different models for soil moisture, mineral content, etc. Anticipating future applications, we have made the hardware and software changes to the system as general as possible.

For initial surveys a multiple array of up to six (6) magnetometer sensors (Schonstedt GA-52B) giving a data point every foot and a rate of coverage of 10 to 15 acres per 8-hour day.

8.0 Acknowledgments

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